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THESIS
FOR THE
DETERMINATION
OF THE VALUE
OF
CARPENTER'S
COAL CALORIMETER
AS AN ACCURATE MEASURER
OF HEAT.

A. H. Miller.

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Thesis for the determination of the value of a Carpenter Coal Calorimeter, as a Heat Measurer.

Experiments for this determination were carried out along two lines.

In the first, the heat was applied by means of sending an electric current through a platinum wire resistance in the body of the calorimeter, the current being supplied, excepting in one experiment, by secondary cells.

In the second case, the heat was applied by burning coal in the body of the calorimeter, the coal used in the various experiments being taken from one thoroughly ground and mixed sample.

In the first case, current passed from the leads from the cells, through a knife switch, an ammeter (#27) which read up to six amperes, and the resistance

of platinum. This platinum resistance consisted of a piece of platinum wire .015" in diameter, and 1.5" long. Oxygen was passed continually through the calorimeter, at the normal rate for which the calorimeter is made, which is such that the difference of pressure on the two sides of an orifice through which the oxygen (or products of combustion if such are formed) passes, is about 8½ or 9 inches of water, measured by a water manometer. This passage of oxygen reproduces the actual working conditions of the calorimeter as nearly as possible while carrying out this method. A low reading voltmeter (5 volts, #23) was placed across the heavy copper leads which led directly to the platinum wire, and in which heating losses were negligable.

At first readings were taken of time,

current, voltage, scale reading, temperature (outside air) and the difference of pressure inside and outside of the calorimeter, taken by means of a water manometer fixed to the instrument. At the end of each experiment data were obtained for finding the rate of radiation from the calorimeter, being determined by taking simultaneous readings of time and scale divisions, no heat passing in the meanwhile into the calorimeter except by radiation.

It was assumed that this rate of radiation was constant throughout the experiment. This assumption is in accordance with the printed instructions accompanying the calorimeter. It was found that this method gave results which varied very greatly with one another (see Tests #1, 2, & 3, pages 14 to 25). It was decided to find

whether there was a relation between temperature changes and rate of radiation which could be used in correcting for radiation. To do this, readings were taken of temperature (outside air) and scale readings, the temperature being varied by passing current from a 110 volt lighting circuit through a large resistance frame. Curves were plotted between scale readings and time (which was also read) and between temperature and time. (See pages 26 & 27.) No relation which could be used was found, but it was seen that the radiation curve followed a straight line (approximately). Therefore, the following method of correcting for radiation was adopted: Radiation curves were plotted immediately before and after each experiment. If these curves followed approximately straight lines (as they invariably did), the mean of the two rates of radiation (before and after the

experiment) was assumed as the rate of radiation throughout the experiment, and the correction for radiation was made on that basis.

The "constant" of the calorimeter was now investigated, to see if it was a constant.

The power in watts put into the calorimeter is known (amperes x volts) This, if the time is known, can be expressed in British Thermal Units. The rise in the column of the calorimeter due to this heat is known, by scale readings, and the application of the radiation correction. The B.T.U. added per rise in column of one scale division can now be determined. This is the "constant" of the calorimeter, and should be an actual constant, whatever the rate of adding heat, or the amount of heat added.

This is really a calibration of the

calorimeter, but is not in this Thesis used as such, the object being merely to find whether the instrument gave concordant results.

In the second method, a dried and weighed sample of coal was placed in the body of the calorimeter, in an asbestos crucible. The coal was taken from the jar in which the ground sample was kept, spread over a piece of paper, in a thin layer, and dried for forty-five minutes in an oven in which the temperature was kept between 212° F. & 230° F. The crucible was then thoroughly dried (by holding it in a bunsen flame), and weighed. Coal was put into the crucible, and the two were weighed. Then the crucible containing the coal, was placed in the body of the calorimeter, and the oxygen current started. The radiation curve was now made, as above mentioned, and

presently the coal was ignited by means of the platinum wire above mentioned, which was heated for an instant to incandescence, by means of the passage of an electric current. The estimated time during which the current was allowed to flow, was 7 seconds, the amount of heat added during this time by the current being negligable. Reading, both time and scale division, were continued, as were the temperature and pressure readings, until coal was completely consumed. The readings were still continued, in order to get the second radiation curve. When data for this curve had been obtained, the crucible, containing the ash, was removed and weighed. The size of the charge of the calorimeter is known, we have data for radiation corrections. On applying this correction, we get rise due to addition of heat by burning coal. By dividing by the weight of the coal, and by the combustible

which is also obtainable, viz: the number of scale divisions lost, per unit mass of coal, or combustable, consumed. These amounts should be constant, and numerous experiments were made to ascertain whether they were so. (See table 3 curves)

Conclusions.

In the first manner of testing with current, the results were variable to a very great extent, the greatest difference between any two results being 29.5% of the largest result, and the greatest difference between any one result and the mean being 19.4% of the larger.

In the second manner of testing with current, but two tests were made, the difference between the two being 5.03% of the larger.

The difference between the means of these results of these two methods was 2.61% of the larger. (For average results, see page 63)

In the method by burning coal in the calorimeter using "Btu of column per gm. coal", in 9 experiments, the greatest difference between any two was 27.8% of larger, while the greatest difference between any result and the mean was 13.5% of the larger.

It would seem, therefore, that even with the greatest of care in making readings and applying corrections for radiation etc., that the Carpenter Coal Calorimeter is liable to an error of somewhat over 10%

Tables and Curves, etc.

In the tables, "Oxygen Pressure" is the difference of pressure between the inside and outside of the orifice through which the oxygen or products of combustion (if such be present) leaves the instrument, expressed in inches of water.

In the curves, ordinates represent Scale Divisions, and abscissae time, unless otherwise marked.

All weights given in the tests are in grams.

Calibration of the ammeter and voltmeter used was unnecessary, as the desire was simply to compare various tests, not to get absolute values of calibration of the calorimeter.

Description of the Calorimeter

The instrument consists of a combustion chamber (15) which has a removable bottom. The chamber is supplied with oxygen through the tube (23), which was connected with an oxygen tank, pressure being regulated by a valve. The products of combustion are conducted through the spiral tube (28, 29, 31.) The tube ends in a hose nipple (30), from which a hose connection is made to a small chamber, (39) attached to the outer case, and supplied with a manometer, (40). A plug (41) with a pinhole orifice is attached for the discharge of gases. The manometer indicates pressure of gases. Surrounding the combustion chamber is a large closed chamber (1) filled with water and connected with an open glass tube with attached scale (9 & 10). Above the water chamber is a diaphragm (12) which is used to adjust the zero level, by means of screw (14) in the open glass tube, at any desired point. A glass for observing process of combustion is inserted at (33) in top of the combustion chamber, at (34) in top of water chamber, and

at (36) in top of outer case. An opening for filling is provided by removing the plug screw (37) which can also be used for emptying if desired. The plug (17) which stops up the bottom of the combustion chamber, carries a disk (23) on which the fuel for combustion is placed, also two wires (26, 27) passing through tubes of vulcanized fibre which are adjustable in a vertical direction and connected with the platinum wires at the ends, which is used to fire the fuel. On the top of this plug is placed a silver mirror (38) to deflect any radiant heat. Through the centre of the plug passes the tube (23) which supplies oxygen for combustion. The plug is made of alternate layers of rubber and asbestos fibre, the outside only being of metal, which, being in contact with the wall of the chamber, can convey little heat to the outside. The instrument readily slips into an outside case which is nickle plated and polished on the inside so as to reduce radiation; it is supported on the strips of felting (5 & 6).

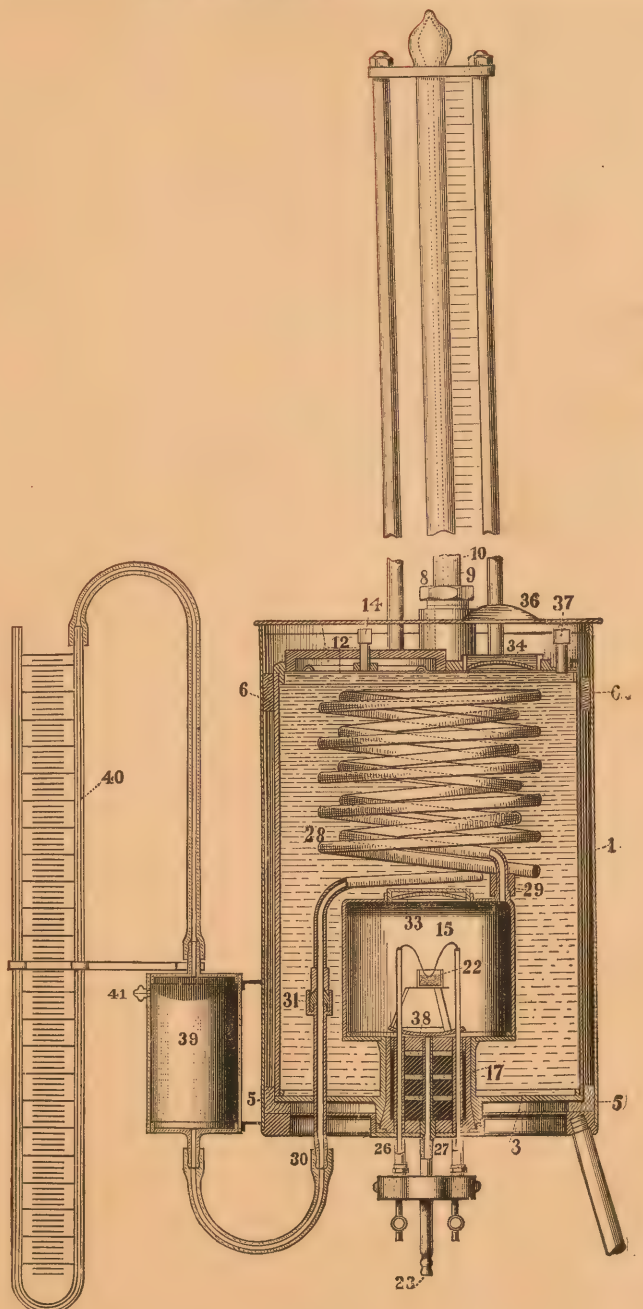
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Fig. 73.

Table #1

Time	Volts	Amperes	Scale	Temp.	Manometer		Oxy. Press.
11·35	.85	6.1	.18	69.0	4.00	4.55	8.55
11·40	.85	6.0	.57	69.0	3.85	4.40	8.25
11·45	.85	6.0	.92	69.5	4.00	4.55	8.55
11·50	.85	6.0	1.30	70.0	4.05	4.60	8.65
11·55	.85	6.0	1.65	70.0	4.00	4.55	8.55
12·00	1.45	8.1	2.20	70.0	3.90	4.45	8.35
12.05	1.44	8.1	2.86	70.0	4.00	4.55	8.55
12·10	1.45	8.2	3.57	70.5	3.85	4.40	8.25
12·15	1.45	8.2	4.35	70.5	4.00	4.55	8.55
12·20	1.45	8.25	5.10	70.5	3.95	4.50	8.45
12·25	1.45	8.25	6.00	70.5	4.00	4.55	8.55
12·30	1.47	8.40	6.70	70.5	4.00	4.55	8.55
12·35	1.47	8.4	7.45	71.0	3.95	4.50	8.45
12·40	1.47	8.4	8.25	71.0	3.85	4.40	8.25
12·45	1.47	8.4	9.10	71.0	4.05	4.60	8.65
12·50	1.47	8.4	9.80	71.0	4.00	4.55	8.55
12·55	1.47	8.4	10.75	71.5	3.90	4.45	8.35
1.00	1.47	8.4	11.60	71.5	3.85	4.40	8.25

Table #1 (continued)

TIME	VOLTS	AMPERES	SCALE	TEMP.	MANOMETER		OXY. PRESS
1.05	1.47	8.41	12.45	71.5	3.75	4.30	8.05
1.10	1.47	8.41	13.30	71.5	3.75	4.30	8.05
1.15	1.48	8.45	14.13	71.5	4.10	4.65	8.75
1.20	1.48	8.50	14.95	71.5	4.00	4.55	8.55
1.25	1.49	8.50	15.80	71.5	3.90	4.45	8.35
1.30	1.48	8.45	16.70	71.5	4.00	4.55	8.55
1.35	1.47	8.41	17.40	71.0	4.00	4.55	8.55
1.40	1.49	8.50	18.25	71.0	3.95	5.50	8.95
1.41.30			18.50	71.0			
1.45			18.45	71.0	4.05	4.60	8.65
1.50			18.30	71.5	4.00	4.55	8.55
1.55			18.15	72.0	3.90	4.45	8.35
2.05			17.83	72.5	4.00	4.55	8.55
2.10			17.67	72.5	4.00	4.55	8.55
2.20			17.35	72.5	3.70	4.25	7.95
2.30			17.07	73.0	3.70	4.25	7.95
2.40			16.80	73.0	3.95	4.50	8.45
2.50			16.65	730	3.85	4.40	8.35

Methods of calculations.

$V \times A =$ Watts.

$\frac{W}{746} = HP$ $\qquad$ $HP \times 33000 \times \text{Time} = \text{ft. lbs.}$

$\frac{\text{ft. lbs.}}{778} = \text{B.T.U.}$ $\qquad$ $\frac{\text{B.T.U.}}{\text{Scale div.}} = \text{B.T.U. per sc div.}$

$\therefore$ B.T.U. per sc div. $= \frac{V \times A \times 33000 \times T}{746 \times 778 \times (S+R)}$

where R = correction for radiation

Test #1

Time, 11.35 — 11.55 —— 20 minutes

From radiation curve, radiation in 20 min = .5 sc. div.

B.T.U. per sc. div. $= \frac{.85 \times 6.02 \times 33000 \times 20}{746 \times 778 \times (1.97 + .5)} = \underline{2.99}$

Time, 11.55 — 12.25 —— 30 min.

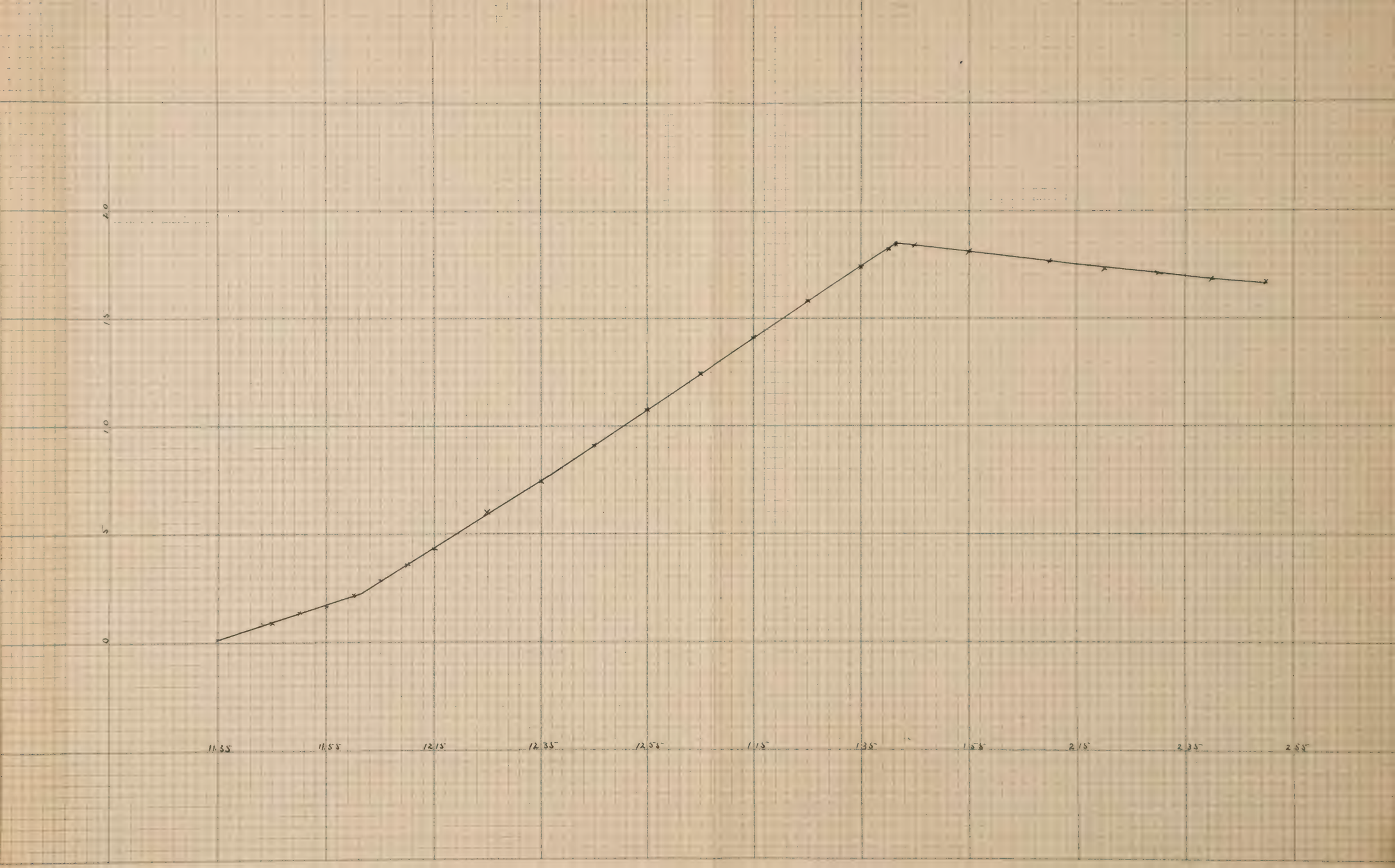
From radiation curve, radiation in 30 min = .76 sc. div.

B.T.U. per sc. div $= \frac{1.45 \times 8.22 \times 33000 \times 30}{746 \times 778 \times (9.35 + .76)} = \underline{3.97}$

Time, 12.25 — 1.35 —— 70 min.

Radiation, 70 min. = 2. sc. div

B.T.U. per sc. div $= \frac{1.47 \times 8.42 \times 33000 \times 70}{746 \times 778 \times (11.40 + 2.00)} = \underline{3.67}$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1.5
1.0
.5
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11.35
11.55
12.15
12.35
12.55
1.15
1.35
1.55
2.15
2.35
2.55

Curve #1

Heat supplied by means of current from two storage cells.

At 11.55 the cells were charged, causing rise of potential.

At 1.41.30 the circuit was broken, and the remainder of the curve is simply a radiation curve.

Table # 2

TIME	VOLTS	AMPERES	SCALE	TEMP	MANOMETER		OXY. PRESS
12.05	1.15	7.81	.00	77.0	3.95	3.95	7.90
12.10	1.03	7.39	.60	77.5	4.00	4.00	8.00
12.15	1.01	7.35	1.25	79.0	3.80	3.80	7.60
12.20	1.01	7.30	1.75	79.0	4.00	4.00	8.00
12.25	.99	7.29	2.40	80.0	3.90	3.90	7.80
12.30	.97	7.28	2.90	80.0	3.75	3.75	7.50
12.35	1.01	7.22	3.50	80.0	4.05	4.05	8.10
12.40	1.15	7.89	4.10	80.5	3.90	3.90	7.80
12.45	1.25	8.30	4.70	81.0	3.85	3.85	7.70
12.50	1.22	8.21	5.46	81.5	4.1	4.1	8.20
12.55	1.22	8.21	6.35	81.5	3.95	3.95	7.90
1.00	1.22	8.20	7.19	81.5	3.85	3.85	7.70
1.05	1.25	8.22	8.05	82.0	3.70	3.70	7.40
1.10	1.25	8.26	8.93	82.5	4.05	4.05	8.10
1.15	1.25	8.30	9.82	82.5	3.95	3.95	7.90
1.20	1.24	8.32	11.55	82.5	4.00	4.00	8.00
1.30	1.24	8.21	12.44	82.0	3.85	3.85	7.70
1.35	1.21	8.20	13.25	81.0	4.05	4.05	8.10

Table #2 (continued)

TIME	VOLTS	AMPERES	SCALE	TEMP.	MANOMETER		OXY. PRESS
1.40	1.20	8.17	14.05	80.5	3.9	3.9	7.80
1.55	1.20	8.20	16.25	80.0	4.2	4.2	8.40
2.00	1.20	8.21	16.95	80.0	4.0	4.0	8.00
2.05	1.20	8.25	17.64	79.5	3.7	3.7	7.40
2.10	1.22	8.25	18.35	79.5	4.1	4.1	8.20
2.12			18.40				
2.13			18.40				
2.14			18.38				
2.15			18.37	78.5	3.8	3.8	7.60
2.20			18.25	78.0	4.2	4.2	8.40
2.30			17.80	77.5	3.6	3.6	7.20
2.40			17.35	77.5	4.2	4.2	8.40
2.50			16.92	77.5	3.6	3.6	7.20
3.00			16.50	77.0	4.2	4.2	8.40
3.10			16.00	77.0	3.6	3.6	7.20

Test # 2

Time, 12.05 — 12.45 —— 40 minutes.

Mean voltage during this time = 1.03 volts.

Mean current " " " = 7.40 amperes.

From radiation curve, Radiation in 40 min = 1.75 sec. dis.

$$\text{B.T.U. per sec. dis} = \frac{1.03 \times 7.40 \times 33000 \times 40}{746 \times 778 \times (4.70 + 1.75)} = \underline{2.69}$$

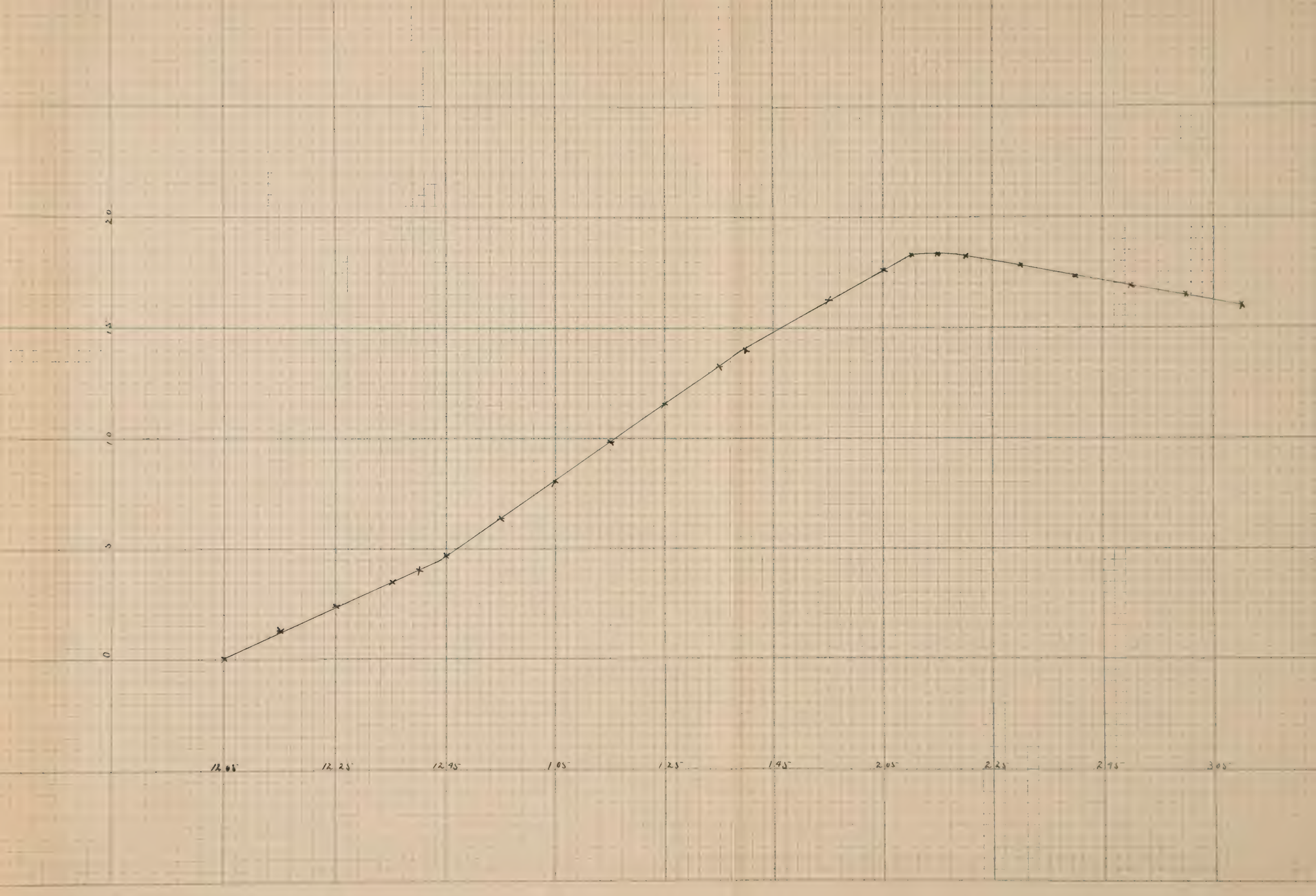
Time, 12.45 — 2.10 —— 85 minutes.

Mean voltage during this time = 1.224

" current " " " = 8.246

From radiation curve, radiation in 85 min. = 3.70 sec. dis.

$$\text{B.T.U. per sec. dis} = \frac{1.224 \times 8.246 \times 33000 \times 85}{746 \times 778 \times (13.65 + 3.70)} = \underline{2.80}$$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3.05

Course # 2

Heat supplied by means of current from 110 volt lighting circuit, resistance being placed in series until the desired potential difference was obtained at the terminals of the platinum resistance.

Table #3

TIME	VOLTS	AMPERES	SCALE	TEMP	MANOMETER		OXY. PRESS
11.15	1.34	8.5	.05	76.5	4.1	4.1	8.2
11.20	1.34	8.5	.90	76.5	4.1	4.1	8.2
11.25	1.34	8.5	1.78	77.0	3.8	3.8	7.6
11.30	1.34	8.5	2.65	77.0	4.1	4.1	8.2
11.35	1.34	8.5	3.52	77.0	4.0	4.0	8.0
11.40	1.34	8.5	4.42	77.0	3.9	3.9	7.8
11.45	1.34	8.5	5.21	77.0	3.9	3.9	7.8
11.50	1.34	8.5	6.24	77.0	3.5	3.5	7.0
11.55	1.34	8.5	7.03	77.0	4.0	4.0	8.0
12.00	1.34	8.5	7.90	77.0	3.9	3.9	7.8
12.35	1.34	8.5	9.17	78.5	4.1	4.1	8.2
12.40	1.34	8.5	9.95	78.5	4.0	4.0	8.0
12.45	1.34	8.5	10.76	78.5	4.0	4.0	8.0
12.50	1.34	8.5	11.66	78.5	4.0	4.0	8.0
12.55	1.34	8.5	12.56	78.5	4.0	4.0	8.0
1.00	1.34	8.5	13.45	79.0	4.0	4.0	8.0
1.05	1.34	8.5	14.34	79.0	3.9	3.9	7.8
1.10	1.34	8.5	15.20	78.5	4.1	4.1	8.2

Table # 3 (continued)

TIME	VOLTS	AMPERES	SCALE	TEMP.	MANOMETER		OXY. PRESS
1.15	1.34	8.5	16.02	78.5	4.0	4.0	8.0
1.20	1.34	8.5	16.88	78.5	4.0	4.0	8.0
1.25	1.34	8.5	17.72	78.5	4.0	4.0	8.0
1.26			17.71				
1.27			17.70				
1.28			17.68				
1.30			17.66	78.5	4.0	4.0	8.0
1.35			17.55	78.5	3.95	3.95	7.9
1.40			17.37	78.5	3.9	3.9	7.8
2.05			16.45	78.0	4.2	4.2	8.4
2.10			16.07	78.0	4.0	4.0	8.0
2.25			15.70	78.0	3.9	3.9	7.8

Test # 3

Time, 11.15 — 12.00 —— 45 minutes.

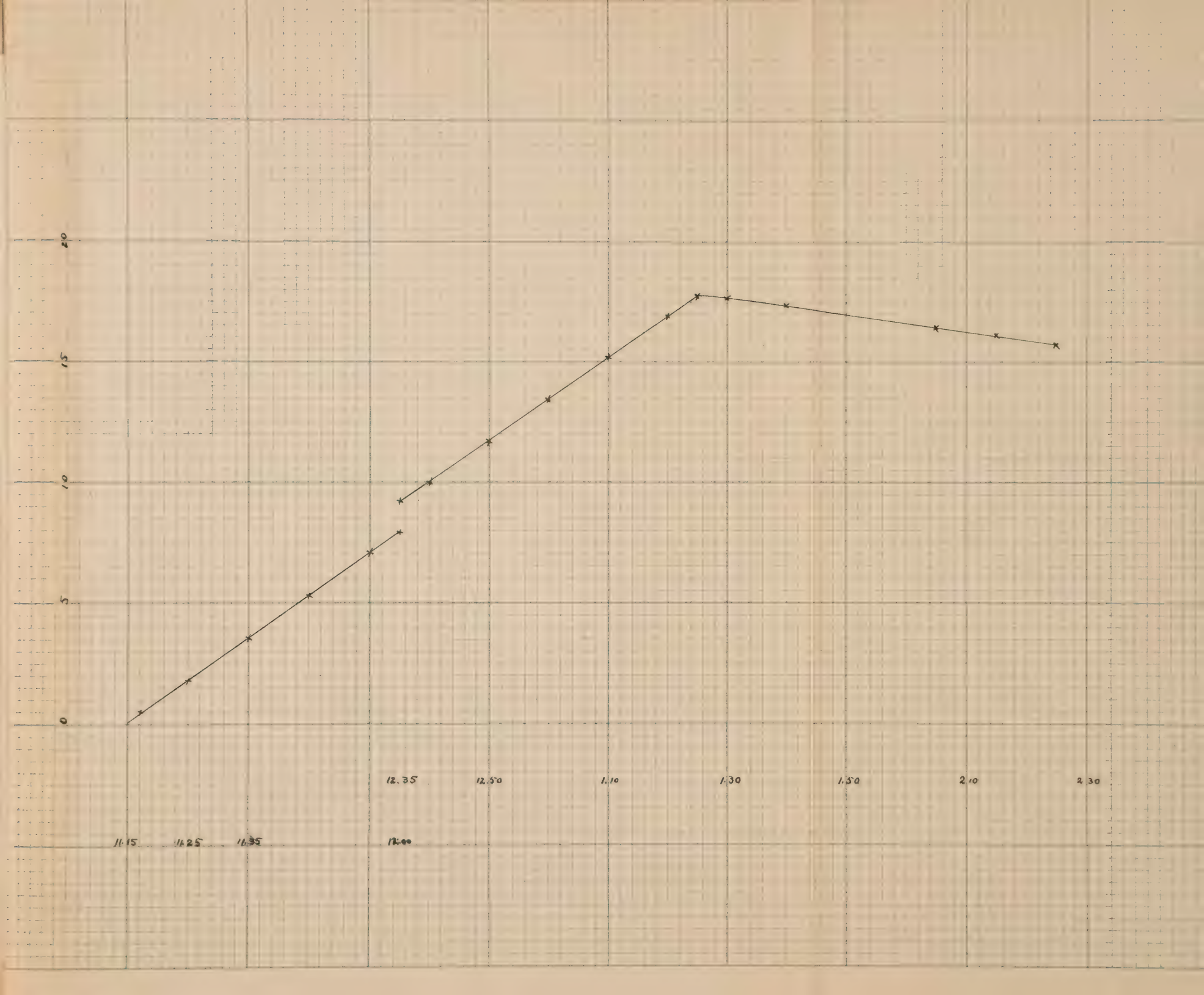
Radiation in 45 min = 1.50 sc. div.

$$\text{B.T.U. per sc. div} = \frac{1.34 \times 8.50 \times 33000 \times 45}{746 \times 778 \times (7.85 + 1.50)} = 3.11$$

Time, 12.35 — 1.25 — 50 min

Radiation in 50 min = 1.65 sc div.

$$\text{B.T.U. per sc. div} = \frac{1.34 \times 8.50 \times 33000 \times 50}{746 \times 778 \times (8.35 + 1.65)} = 3.16$$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2.10
2.30
11.15
11.25
11.35
12.00

Course #3

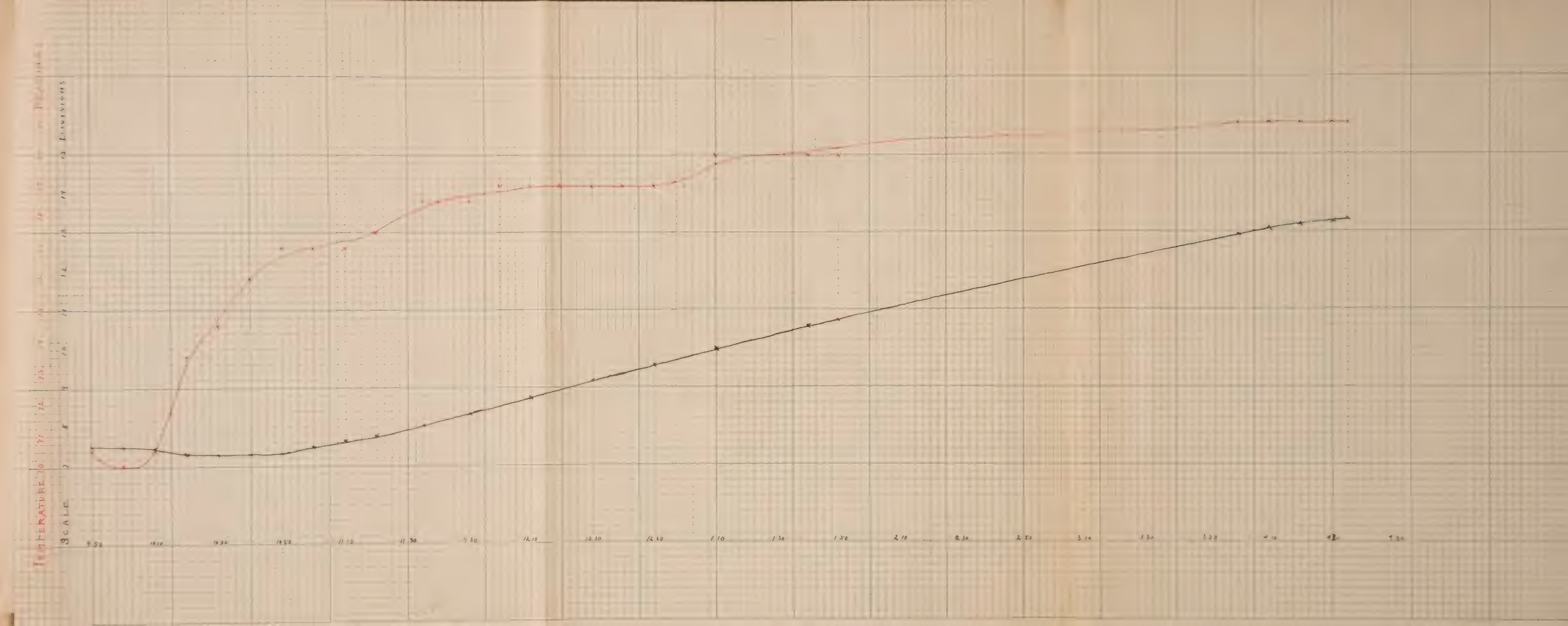
Heat supplied by current from 3 storage cells.

at 12.00 o'clock the supply of oxygen ran out.

at 12.35, new tank was substituted, experiment continued.

Test to find a relation between change of temp. & rise of column

TIME	TEMP	SCALE	OXY. PRESS	TIME	TEMP	SCALE	OXY. PRESS
9.50	70.5	7.50	8.4	11.50	78.5	8.35	8.6
9.55	70.5	7.54	9.0	12.00	79.0	8.55	8.2
10.00	70.0	7.50	7.4	12.10	79.0	8.75	8.0
10.05	70.5	7.45	7.4	12.20	79.0	8.95	8.2
10.10	70.5	7.42	8.6	12.30	79.0	9.15	8.2
10.15	71.5	7.36	8.1	12.40	79.0	9.35	8.2
10.20	73.5	7.32	7.9	12.50	79.0	9.55	9.0
10.25	74.0	7.30	7.9	1.00	79.0	9.75	8.0
10.30	74.5	7.27	7.9	1.10	80.0	9.97	7.9
10.35	75.5	7.27	8.2	1.15	80.0	10.07	7.9
10.40	76.0	7.29	8.2	1.40	80.0	10.57	8.3
10.45	76.5	7.31	8.1	1.45	80.0	10.67	8.3
10.50	77.0	7.36	7.9	1.50	80.0	10.77	8.3
10.55	77.0	7.41	7.8	4.00	81.0	12.92	7.7
11.00	77.0	7.47	7.8	4.05	81.0	13.01	8.3
11.10	77.0	7.64	8.8	4.10	81.0	13.08	8.3
11.20	77.5	7.74	8.8	4.15	81.0	13.15	8.3
11.35	78.5	8.05	8.8	4.20	81.0	13.22	8.3
11.40	78.5	8.15	8.8	4.25	81.0	13.29	8.3


TEMPERATURE
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10 30
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12 50
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1 50
2 10
2 30
2 50
3 10
3 30
3 50
4 10

Curves between temperature & time, &
scale & time.

Heat was generated in the room which
contained the calorimeter, in order that
some connection between the two
curves might be found.

The heat was generated by means of
passing current through a large resistance
frame from a 110 volt lighting circuit.

No heat passed into the calorimeter except
from the outside air, by radiation.

Table #4

TIME	VOLTS	AMPERES	TEMP.	SCALE	OXY. PRESS
12.40			80.0	.37	9.2
12.50			80.0	.45	8.8
12.55			79.9	.52	8.8
1.00			79.5	.60	8.2
1.05			79.5	.67	9.0
1.10			80.0	.74	9.0
1.20			80.0	.87	9.0
1.25			80.0	.96	9.0
1.30			80.0	1.06	9.0
1.35			80.5	1.13	9.0
1.40			80.5	1.22	9.0
1.45	1.09	7.01	80.5	1.30	9.0
1.50	1.07	7.01	80.5	1.91	9.4
2.00	1.07	7.00	81.0	3.24	9.4
2.05	1.07	7.01	81.0	3.92	9.4
2.10	1.06	7.01	81.0	4.58	9.4
2.15	1.07	7.00	81.3	5.26	9.4
2.20	1.06	7.00	81.5	5.93	9.4
2.30	1.06	7.00	81.5	7.34	9.4

Table #4 (continued)

TIME	VOLTS	AMPERES	TEMP	SCALE	OXY. PRESS.
2.35	1.05	7.00	81.5	8.00	9.4
2.40	1.06	7.00	81.5	8.56	9.4
2.45	1.05	7.00	81.5	9.16	9.4
2.50	1.05	7.00	81.5	9.82	9.3
3.00	1.05	7.00	81.5	11.09	9.2
3.05	1.06	7.00	81.5	11.73	9.2
3.10	1.06	7.00	81.5	12.34	9.2
3.15	1.06	7.00	81.5	12.90	9.2
3.20			82.0	12.92	9.2
3.25			82.0	12.90	9.0
3.35			82.0	12.82	8.8
3.40			82.0	12.79	9.1
3.45			82.0	12.74	9.1
3.50			82.0	12.70	9.1
4.00			82.0	12.64	9.2
4.10			82.0	12.56	9.2
4.25			82.0	12.45	9.0
4.40			82.0	12.30	8.8

Test #4

Rise of column before applying heat, (radiation) = 1.5 sc. div.

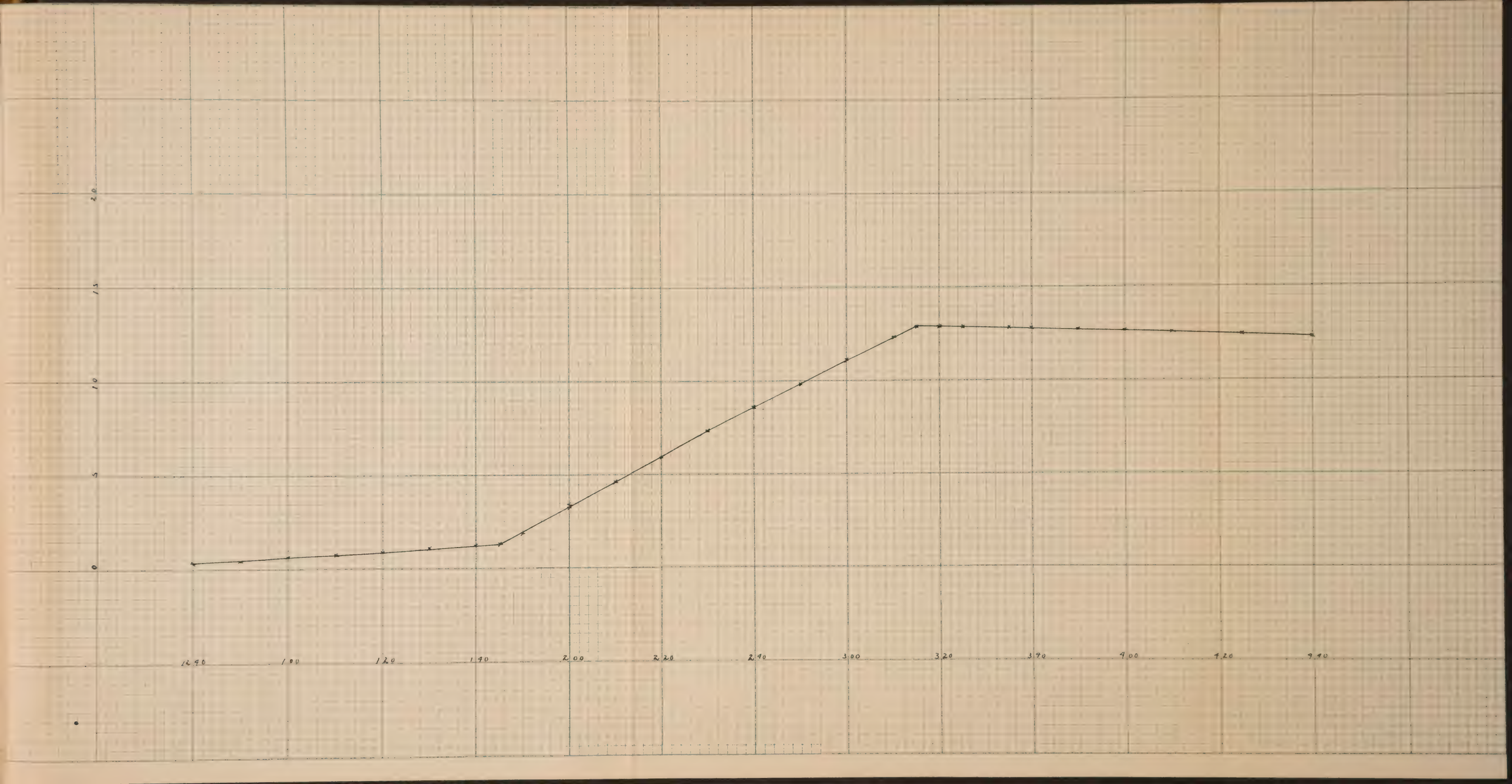
" " " after " " " " = -.5 " "

Correction for radiation (per hr.) = $\frac{1 - .5}{2}$ = .25

Rise of column − (1.45 − 3.15 − .90 min) = 11.60

$11.60 - \frac{90 \times .25}{60}$ = 11.23 = rise in column due to current.

B.T.U. per sc. div. = $\frac{1.06 \times 7.00 \times 33000 \times 90}{746 \times 778 \times 11.23}$ = 3.37


20
15
10
5
0
1240
100
120
190
200
220
240
300
320
390
400
420
490

Curve #4

Heat applied by means of current from 3 storage cells.

Curve from 12.40 to 1.45, and from 3.15 to 4.40, radiation curves, before and after heating.

The mean of the two rates of radiation obtained from these curves is assumed to be the rate of radiation during the experiment.

Table #5

TIME	VOLTS	AMPERES	TEMP.	SCALE	OXY. PRESS
12.50			78.5	.76	9.4
12.55			78.5	.83	9.4
1.00			78.5	.87	9.4
1.05			78.5	.90	9.4
1.15			78.5	.97	9.2
1.20			78.5	1.00	9.2
1.25			78.5	1.02	9.1
1.30			78.5	1.05	9.0
1.35			78.5	1.07	9.0
1.40			78.5	1.10	9.0
1.45			78.5	1.13	9.0
1.50	1.60	7.80	78.5	1.17	8.9
1.55	1.74	7.37	79.0	2.13	9.8
2.00	1.75	7.37	79.0	3.16	10.0
2.05	1.75	7.29	79.0	4.21	10.0
2.10	1.80	7.30	79.0	5.29	9.0
2.15	1.72	7.50	79.0	6.40	9.0
2.20	1.70	7.45	79.0	7.50	8.9

Table #5 (continued)

TIME	VOLTS	AMPERES	TEMP.	SCALE	OXY. PRESS
2.25	1.71	2.48	79.0	8.58	8.8
2.30	1.72	2.45	79.0	9.67	9.0
2.35	1.75	2.45	79.0	10.74	9.0
2.40	1.82	2.25	79.5	12.85	8.8
2.45	1.73	2.45	79.5	13.88	8.7
2.50	1.77	2.40	79.5	14.90	8.7
2.55	1.72	2.50	79.5	15.91	9.0
3.00	1.72	2.50	79.5	16.90	9.0
3.05			79.5	16.94	8.2
3.10			79.5	16.80	9.0
3.15			79.5	16.36	9.0
3.25			79.5	15.72	8.9
3.40			79.5	15.30	9.0
3.50			79.5	15.08	8.9
3.55			79.5	14.88	9.0
4.00					

Test # 5

Rise per hour before adding heat = .41

" " " after " " = −2.56

correction for radiation = $\frac{.41 - 2.56}{2}$ = −1.07 per hr.

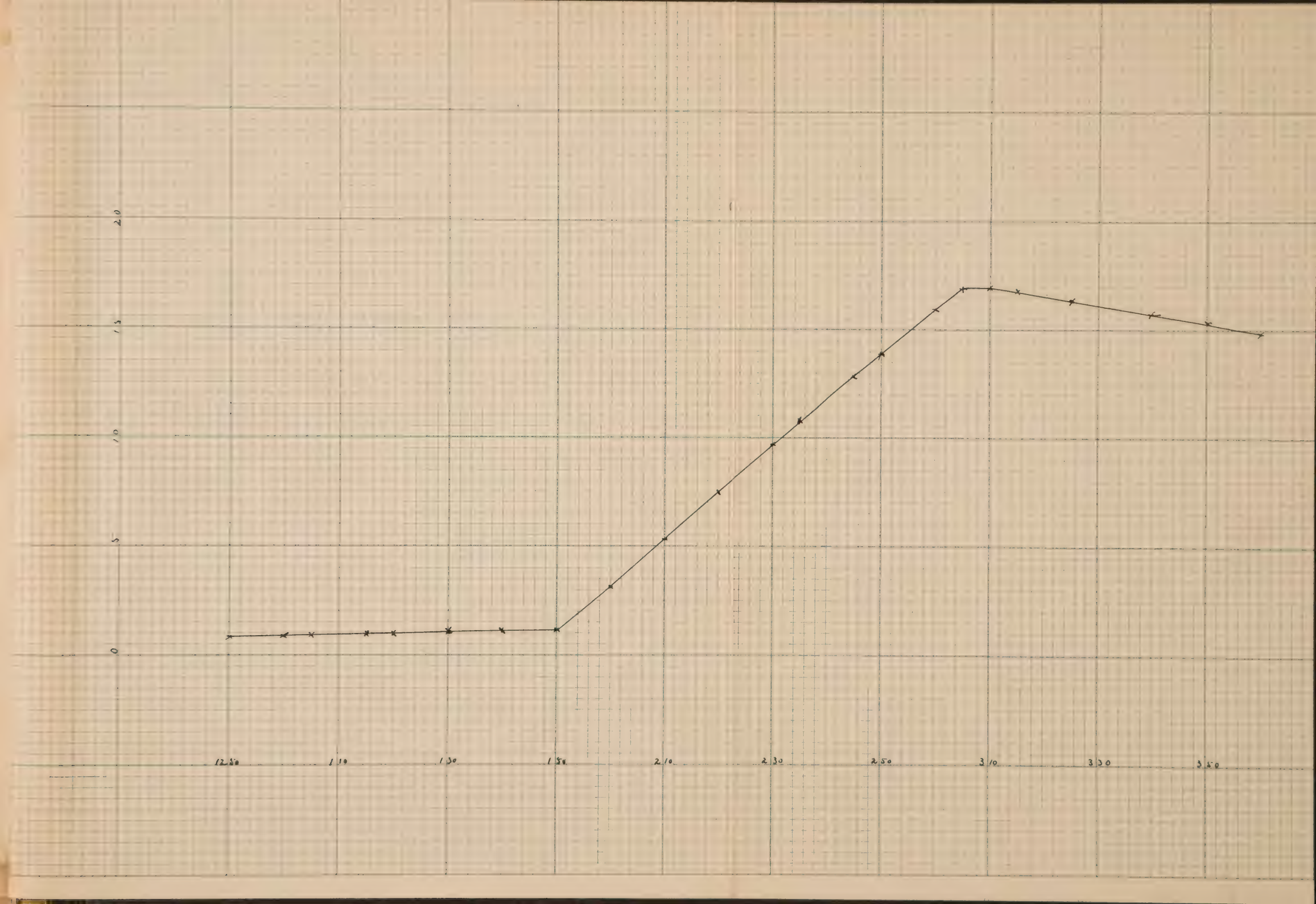
correction for 75 min = $\frac{-1.07 \times 75}{60}$ = −1.34

Rise in 75 min (1.50 — 3.05) = 15.83

corrected rise in 75 min = 15.83 − (−1.34) = 17.17

Mean volts = 1.73 Mean amperes = 7.44

B.T.U. per sec. div = $\frac{1.73 \times 7.44 \times 33000 \times 75}{746 \times 778 \times 17.17}$ = 3.20


20
15
10
5
0
12.50
1 10
1 30
1 50
2 10
2 30
2 50
3 10
3 30
3 50

Curve #5

Heat added by means of current from 3 storage cells.

Curve between 12.30 & 1.30, and between 3.05 & 4.00 radiation curves.

Table #6

TIME	SCALE	TEMP.	OXY. PRESS.
11.40	.76	75.0	9.0
11.45	.78	74.2	9.0
11.50	.80	74.2	9.0
11.55	.83	74.2	8.8
12.00	.86	74.2	8.7
12.05	4.37	74.0	9.3
12.10	8.00	74.5	9.4
12.15	11.02	74.5	8.8
12.20	13.59	74.5	9.0
12.25	15.61	75.0	8.9
12.29	16.64	75.0	8.8
12.35	16.56	75.0	8.4
12.40	16.40	76.0	8.9
12.45	16.20	76.0	9.0
12.55	15.85	76.0	8.7
1.00	15.69	76.0	9.1

Test #6

Coal dried for 45 min between 212° & 230° F

Wt. Crucible = 1.515 gm.

Wt. cruc + coal = 3.345 gm.

Wt. cruc + ash = 1.615 gm.

Wt coal = 1.830 gm. Wt combustable = 1.730 gm

Wt ash = .100 gm % ash = 5.47%

Rise in column before burning coal, 20 min, = .1 sc div

" per hour " " " = .30 sc. div.

Rise in column after " ", 25 min, = -.87 sc. div

" per hour " " " = -2.09 sc div.

Correction for radiation = $\frac{.30 - 2.09}{2}$ = -.895 sc. div per hr.

Rise due to burning, 29 min, = 15.78

Correction for 29 min = $\frac{29}{60} \times -.895 = -.433$

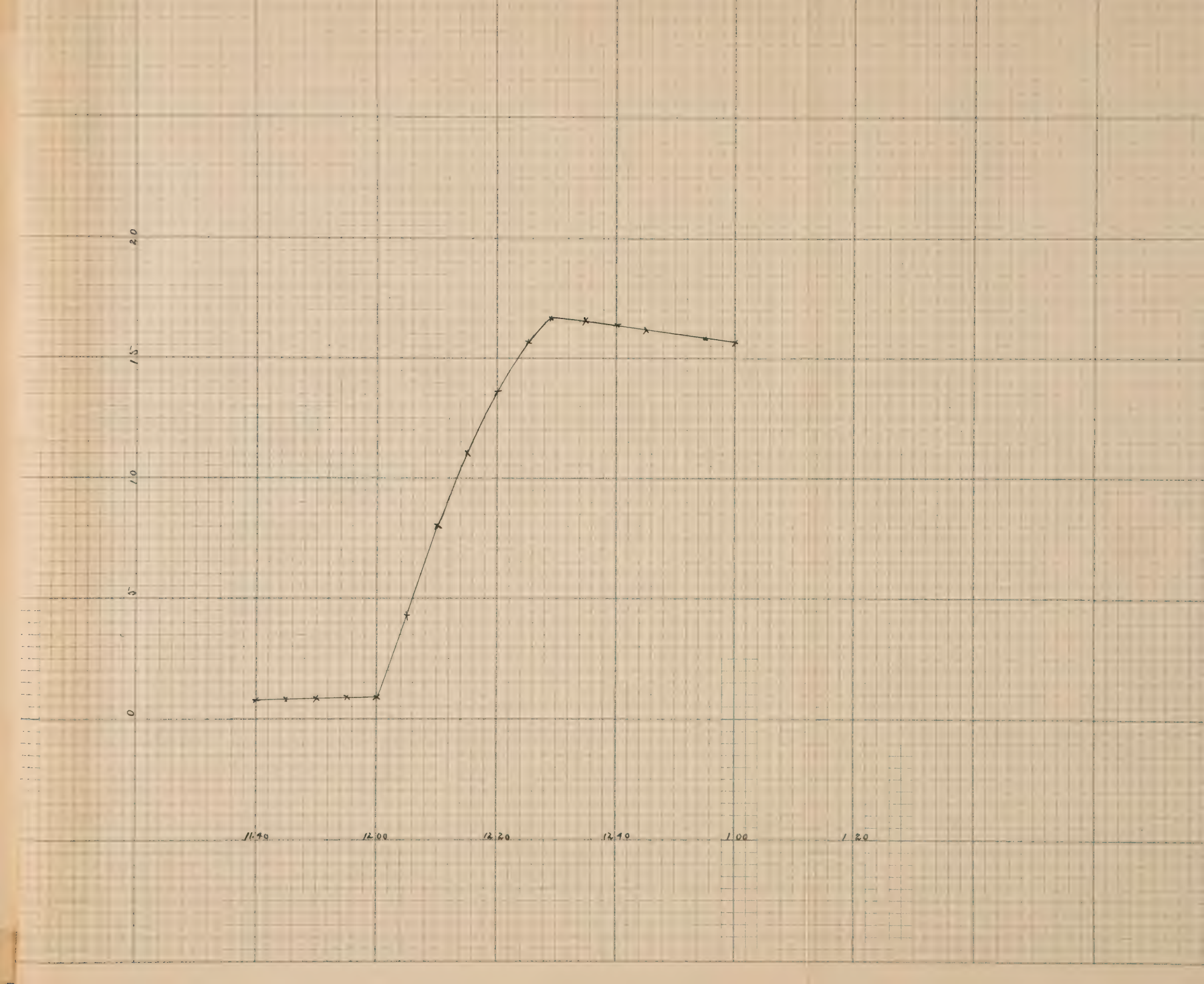
Corrected rise due to burning = 15.78 - (-.433) = 16.21

Rise in column per gm. combustable =

$\frac{16.21}{1.73} = \underline{9.38}$

Rise in column per gm. coal =

$\frac{16.21}{1.83} = \underline{8.89}$


20
15
10
5
0
11.40
12.00
12.20
12.40
1.00
1.20

Curve #6

Heat added by burning coal in the body of the calorimeter.

Curve between 11.40 & 12.00, and between 12.29 & 1.00

are radiation curves.

Coal was ignited at 12.00 o'clock.

Coal consumed at 12.29 o'clock.

Table #7

TIME	SCALE		TEMP.	OXY. PRESS.
11.54	.14		85.5	9.2
12.00	.25		85.5	9.0
12.05	.38		85.5	8.9
12.10	.46		85.5	8.7
12.15	.62		85.0	
12.20	.75		85.0	8.8
12.26	5.35		85.0	9.2
12.30	9.10		85.0	9.0
12.35	11.90		85.0	9.0
12.40	14.95		85.0	9.1
12.45	17.52		85.0	9.1
12.50	18.53	19.53	85.0	9.1
12.53	18.23	20.08	85.0	9.1
12.55	18.24	20.09	85.0	9.0
1.03	18.12	19.97	85.5	9.0
1.05	18.06	19.91	85.5	9.0
1.10	17.92	19.77	85.5	9.0
1.12	17.87	19.72	85.5	9.0

* see page 41

Test #7

Coal dried for 45 minutes between 212° & 230° F

Wt crucible = 1.515

Wt cruc. + coal = 3.415

Wt cruc. + ash = 1.645

Wt coal = 1.900 gm Wt. combustable = 1.770 gm.

Wt. ash = .130 gm % ash = 6.84 %

Rise in column before burning, 26 min, = .61 sc. div.

" per hour " " = 1.39 sc. div

" in column after " , 17 min, = −.37 sc div

" per hour " " = −1.31 sc. div.

correction for radiation = $\frac{1.39 - 1.31}{2}$ = .04 sc div. per hr

Rise due to burning = 19.34 in 35 min.

Correction for 35 min = $\frac{35 \times .04}{60}$ = .023

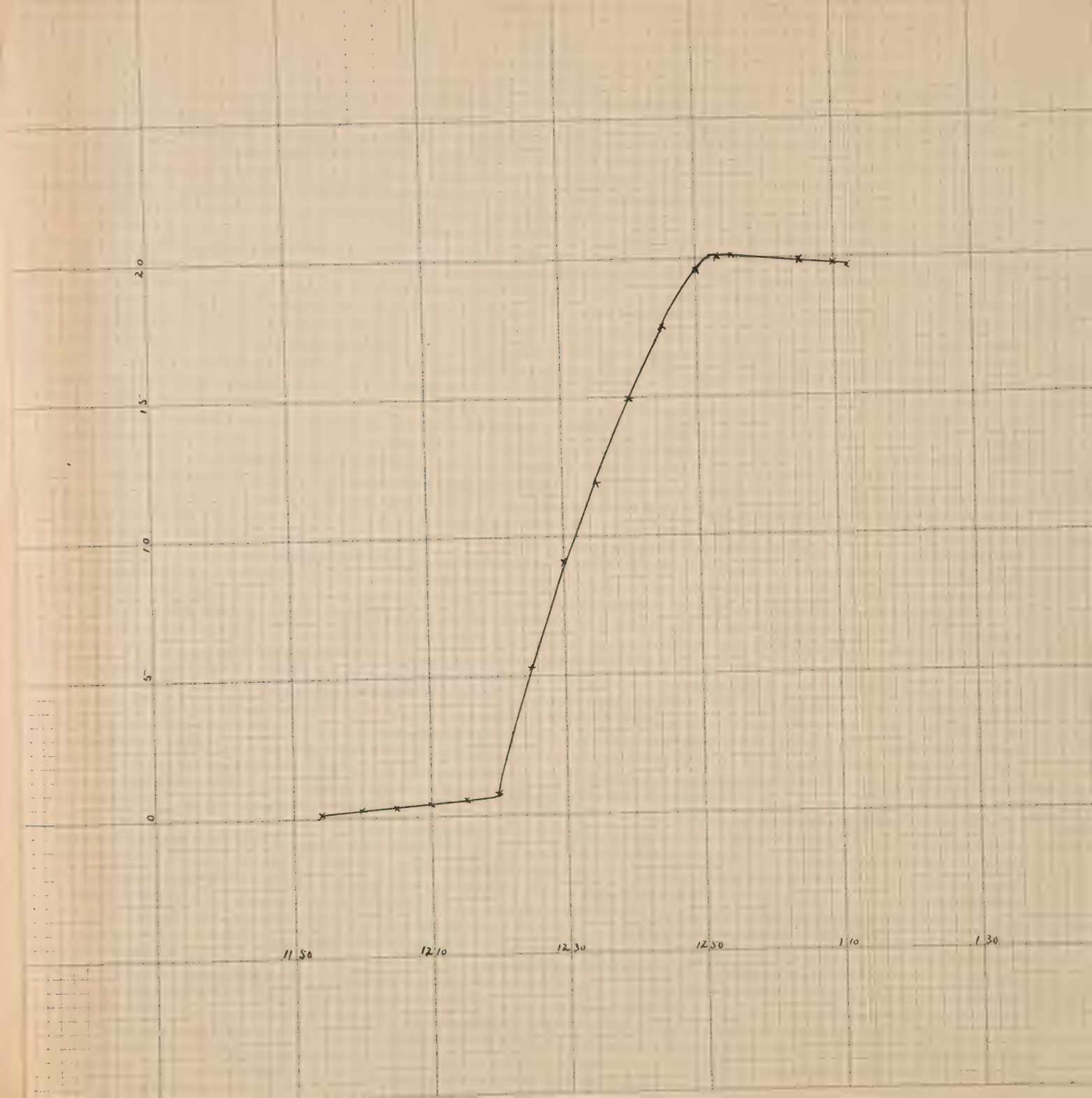
Corrected rise due to burning = 19.32 sc. div.

Rise per gram combustable =

$\frac{19.32}{1.77}$ = 10.9

Rise in column per gm. coal =

$\frac{19.32}{1.90}$ = 10.2


20
15
10
5
0
11.50
12.10
12.30
12.50
1.10
1.30

Curve #7

Heat added by burning coal in the body of the calorimeter.

Radiation curves, 11.54 – 12.20, & 12.55 — 1.12

Coal was ignited at 12.20 o'clock

" " consumed at 12.55 o'clock

At 12.47, the column was moved down 1 scale division, as it approached the upper limit of the scale

At 12.51, the column was moved down .85 scale division

Table #8

TIME	SCALE		TEMP.	OXY. PRESS
3.25	5.70		88.0	9.0
3.31	5.73		88.0	9.2
3.36	5.75		88.0	9.0
3.40	5.76		88.5	8.8
3.45	5.77		88.5	8.6
3.50	5.78		88.5	8.6
3.57	5.80		88.5	8.8
4.00	5.82		89.0	8.6
4.05	8.78		89.0	8.6
4.10	12.40		89.0	9.0
4.16	16.00		89.0	9.2
4.20	17.86		89.0	9.2
4.25	16.90 *	18.35	89.0	9.2
4.26	16.93	18.38	89.0	9.2
4.30	16.90	18.35	89.5	9.0
4.35	16.75	18.20	89.5	9.0
4.40	16.55	18.00	89.5	9.0
4.45	16.38	17.83	89.5	9.0
4.50	16.20	17.65	87.5	9.0

* Read at bottom of 1st column, which was 1.45 sec. dia. comp.

Test #8

Heat added by burning coal in the body of the calorimeter.

Wt. crucible = 1.515 — Coal dried for 45 min

" cruc. + coal = 2.710 — between 212° & 230° F.

" " + ash = 1.595

Wt coal = 1.195 — Wt. combustable = 1.115

Wt. ash = .080 — % ash = 6.71 %

Rise in column before burning, (35 min) = .12 sc. div

" per hour " " = .21 scale divisions

" in column after " , (24 minutes) = .73 sc. div

" per hour " " = 1.82 sc. div.

Correction for radiation = $\frac{.21 - 1.82}{2}$ per hr. = .805 sc. div

Rise in column due to burning, 26 min, 12.56 sc. div.

Correction for 26 min = −.349 sc div.

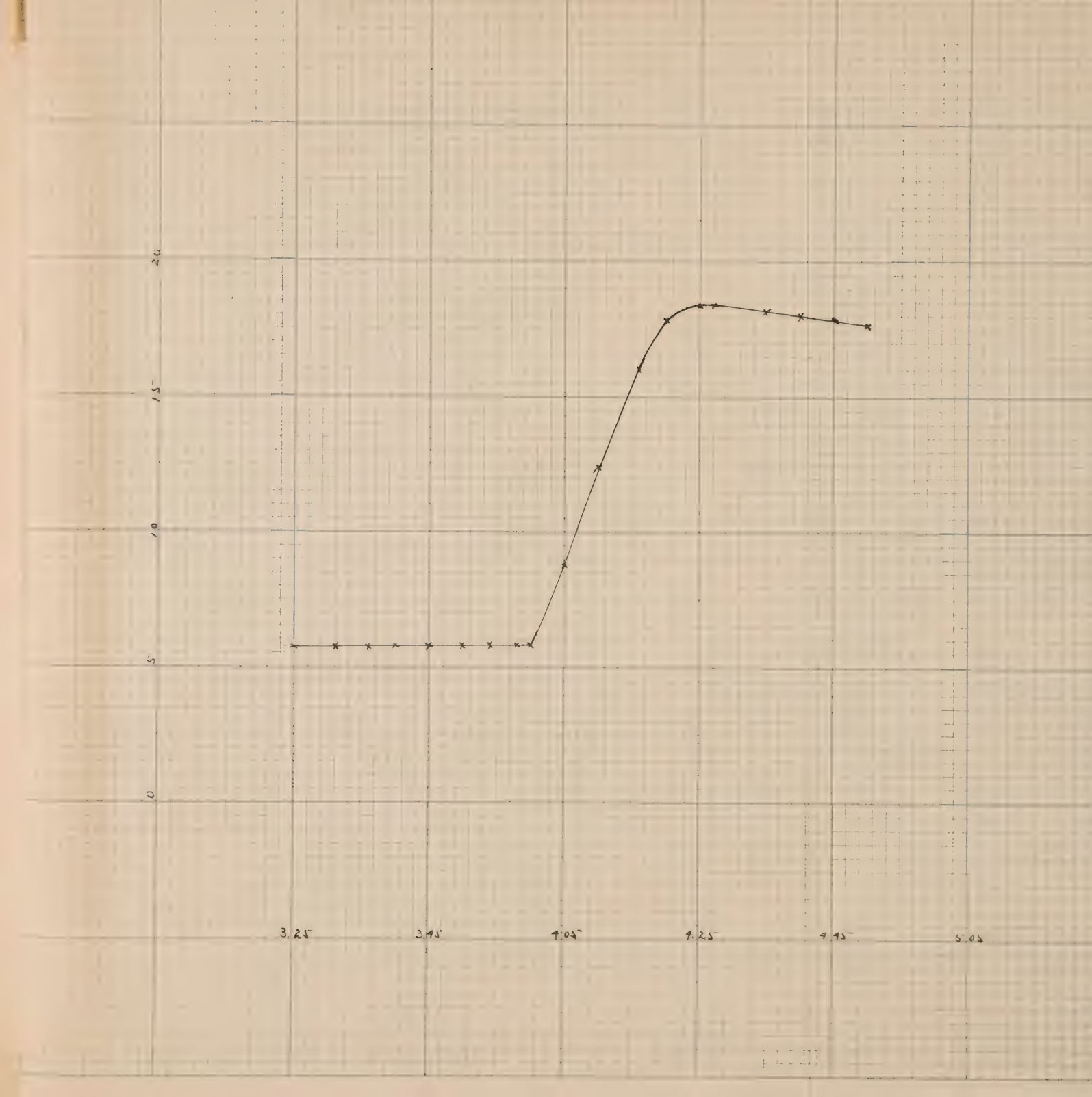
Corrected rise due to burning = 12.91

Rise in column per gram combustable =

$\frac{12.91}{1.115}$ = 11.5 sc. div.

Rise in column per gram. coal =

$\frac{12.91}{1.195}$ = 10.8 sc. div


20
15
10
5
0
3.25
3.75
4.25
4.75
5.25

Curve #8

Heat added by burning coal in body of calorimeter.

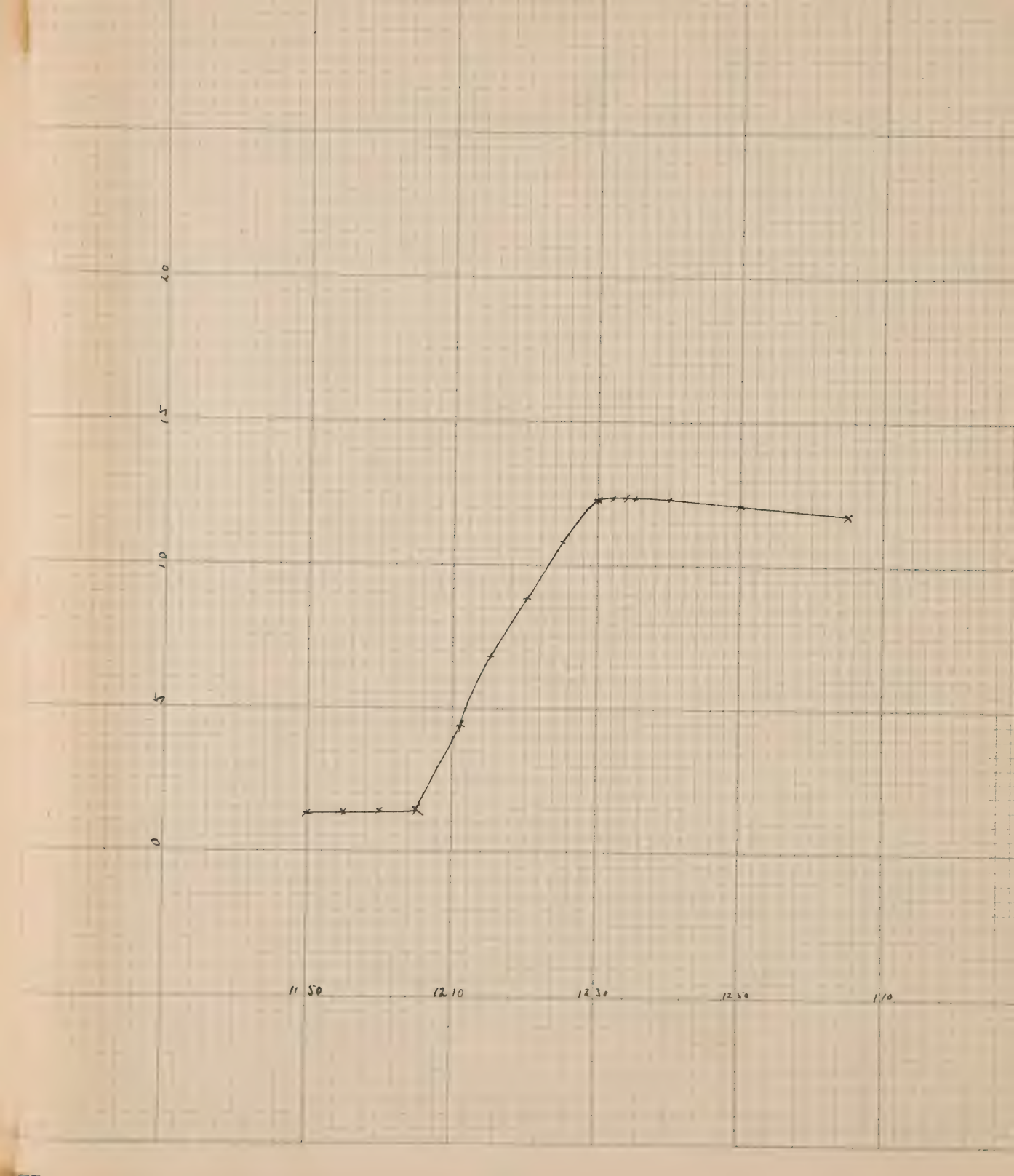
Curve between 3.25 & 1.00, and between 1.26 & 1.50, are radiation curves.

Coal ignited at 1.00 o'clock.

" consumed at 1.26 o'clock.

Table #9

TIME	SCALE	TEMP.	OXY. PRESS.
11.50	1.29	72.0	9.2
11.55	1.35	72.5	9.2
12.00	1.42	72.5	9.0
12.05	1.47	72.5	9.0
12.11	4.90	73.0	8.8
12.15	6 30	73.0	8.8
12.20	8.85	73.0	9.4
12.25	10.85	73.0	9.0
12.30	12.25	73.0	8.6
12.32	12.37		9.3
12.33	12.37	73.0	9.3
12.35	12.35	73.5	9.2
12.40	12.29	73.5	8.8
12.45	12.17	73.5	8.8
12.50	12.07	73.5	9.2
1.05	11.74	73.5	8.6


20
15
10
5
0
11 50
12 10
12 30
12 50
1 10

Curve #9

Heat added by burning coal in the body of the calorimeter.

Curve between 11.50 & 12.05 and between 12.33 & 1.05, are radiation curves

Coal was ignited at 12.05 o'clock

Coal was consumed at 12.33 o'clock.

Table #10

TIME	SCALE	TEMP	OXYGEN
2.01	1.02	81.5	9.0
2.05	1.10	81.5	9.0
2.10	1.22	81.5	8.8
2.15	1.35	81.5	9.2
2.25	1.60	81.5	9.0
2.30	1.75	81.5	8.8
2.35	9.50	81.5	9.0
2.40	7.5-1	81.5	9.2
2.45	10.10	81.5	9.2
2.53	13.40	81.5	8.8
2.55	14.05	81.5	8.9
2.58	14.65		
3.00	14.70	82.0	8.8
3.01	14.70		
3.05	14.70	82.0	8.8
3.10	14.68	82.0	8.6
3.15	14.65	82.0	8.8
3.20	14.62	82.0	8.8
3.30	14.55	82.0	9.0

Test #10

Coal dried for 45 min between 212° & 230° F

Wt. crucible = 1.515

Wt. cru + coal = 2.895

Wt cru + ash = 1.610

Wt coal = 1.380 Wt combustable = 1.285

Wt ash = .095 % ash = 6.89%

Rise in column before burning (29 min) = .73 sc. div

" per hour " " = 1.51 sc. div

" in column after " (25 min) = −.15 sc. div

" per hour " " = −.36 sc. div

Correction for radiation = $\frac{1.51-.36}{2}$ = .185 sc. div per hr.

Rise due to burning, 30 min = 12.95 sc. div.

correction for 30 min = .092 sc. div

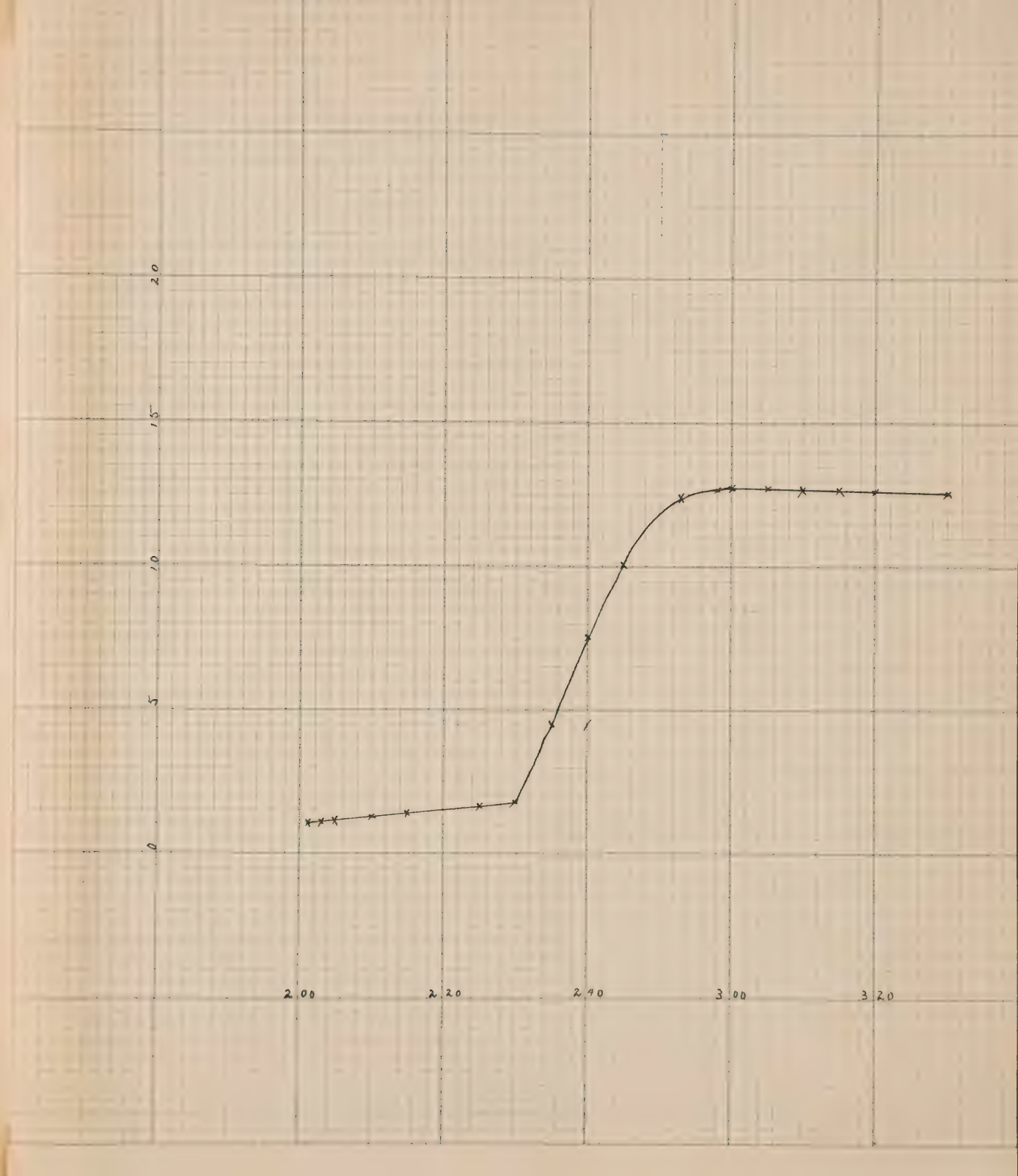
Corrected rise due to burning = 12.86 sc. div.

Rise in column per gram combustable:

$\frac{12.86}{1.285}$ = 10.0 sc. div

Rise in column per gram coal =

$\frac{12.86}{1.385}$ = 7.36 sc. div


2.0
1.5
1.0
.5
0
2.00
2.20
2.40
3.00
3.20

Curve #10

Heat added by burning coal in body of calorimeter

Curve between 2.01 & 2.30, and between 3.05 & 3.30

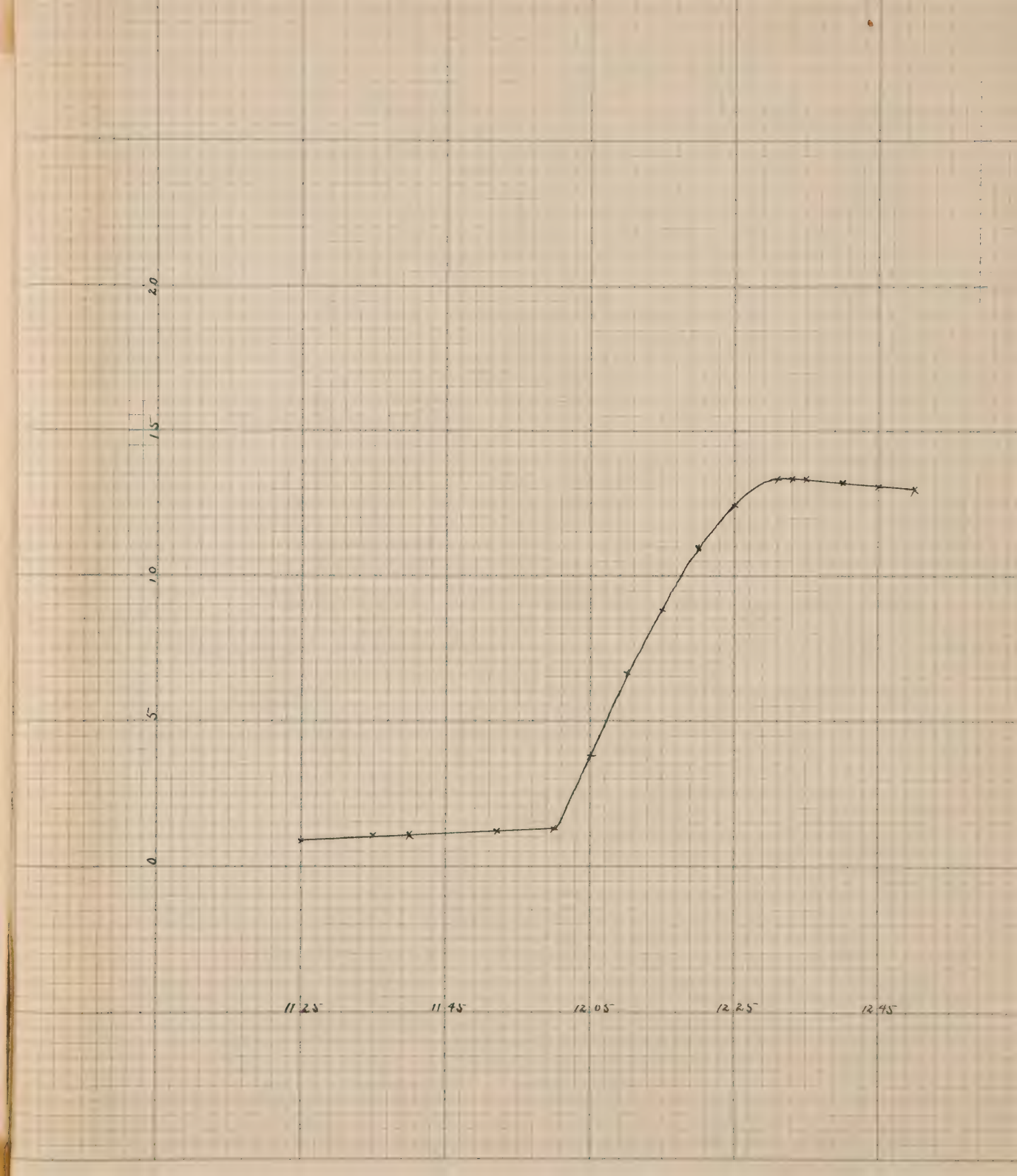
radiation curves.

Coal ignited at 2.30 o'clock

Coal consumed at 3.00 o'clock.

Table #11

TIME	SCALE	TEMP	OXY. PRESS
11.25	.90	75.5	9.4
11.35	1.02	75.5	9.2
11.40	1.07	75.5	9.0
11.52	1.20	75.5	9.0
12.00	1.28	75.5	8.8
12.05	3.85	76.0	9.0
12.10	6.60	76.0	9.0
12.15	8.85	76.0	9.0
12.20	10.97	76.0	8.8
12.25	12.44	76.0	8.8
12.31	13.35	76.0	9.0
12.33	13.35		
12.35	13.33	76.0	9.0
12.40	13.23	76.0	9.0
12.45	13.12	76.0	9.0
12.50	13.00	76.0	9.0


0
5
10
15
20
11 25
11 45
12 05
12 25
12 45

Curve # 11

Heat added by burning coal in body of calorimeter

Curve between 11.25 & 12.00, and between 12.31 &

12.50, radiation curves.

Coal ignited, 12.00 o'clock

Coal consumed, 12.31 o'clock

Table #12

TIME	SCALE	TEMP	OXY. PRESS
11.40	.66	23.5	9.0
11.45	.65	23.5	9.0
12.04	.59	23.5	8.8
12.10	.57	23.5	8.6
12.15	.56		
12.22	.55	24.0	9.0
12.25	2.35	24.0	9.0
12.30	5.00	24.5	8.8
12.35	7.35	24.5	8.8
12.40	9.60	24.5	8.8
12.45	11.20	24.5	8.8
12.48	11.75		
12.50	11.75	25.0	8.8
12.55	11.67	25.0	8.8
1.00	11.52	25.5	8.8
1.05	11.35	25.5	8.8
1.10	11.20	25.5	8.8

Test #12

Coal dried for 45 min between 212° & 230° F

Wt crucible 1.435

Wt cruc. + coal 2.765

Wt cruc + ash 1.525

Wt coal = 1.330 Wt combustable = 1.240

Wt ash = .090 % ash = 6.76 %

Rise in column before burning, (30 min) = -.09 sc. div

" per hour " " = -.18 sc. div

" in column after burning, (20 min) = -.55 sc. div

" per hour " " = -1.65 sc. div

Correction per radiation = $\frac{-.18 - 1.65}{2}$ = -.92 sc. div. per hr.

Rise due to burning (28 min) = 11.20 sc. div.

correction for 28 min = -.43

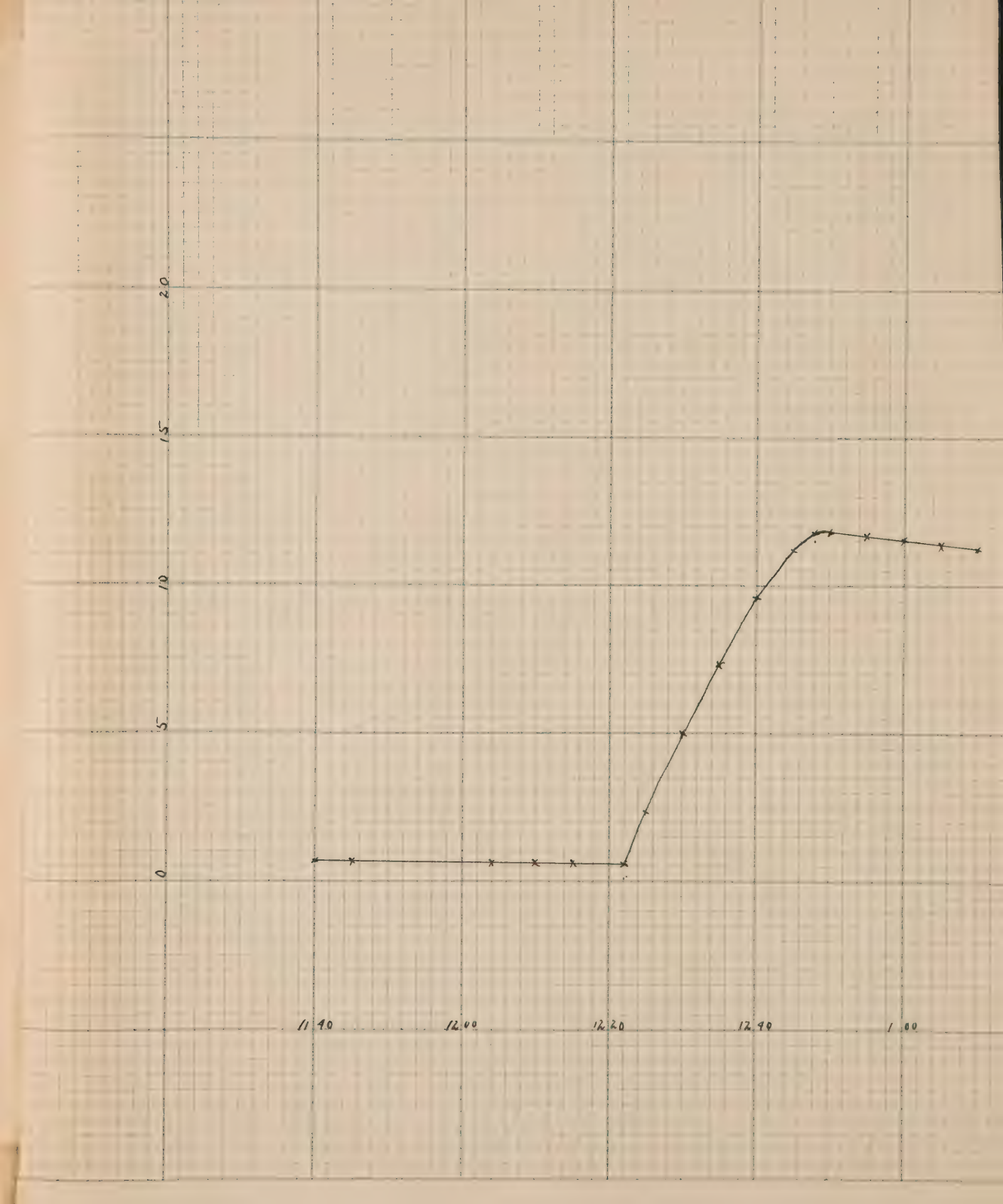
Corrected rise due to burning = 11.63 sc. div.

Rise of column per gram combustable =

$\frac{11.63}{1.240}$ = 9.38 sc. div

Rise of column per gram coal =

$\frac{11.63}{1.330}$ = 8.72 sc. div


2.0
1.5
1.0
.5
0
11.40
12.00
12.20
12.40
1.00

Course #12,

Heat added by burning coal in body of calorimeter

Curve between 11.40 & 12.22, & between 12.50 & 4.10

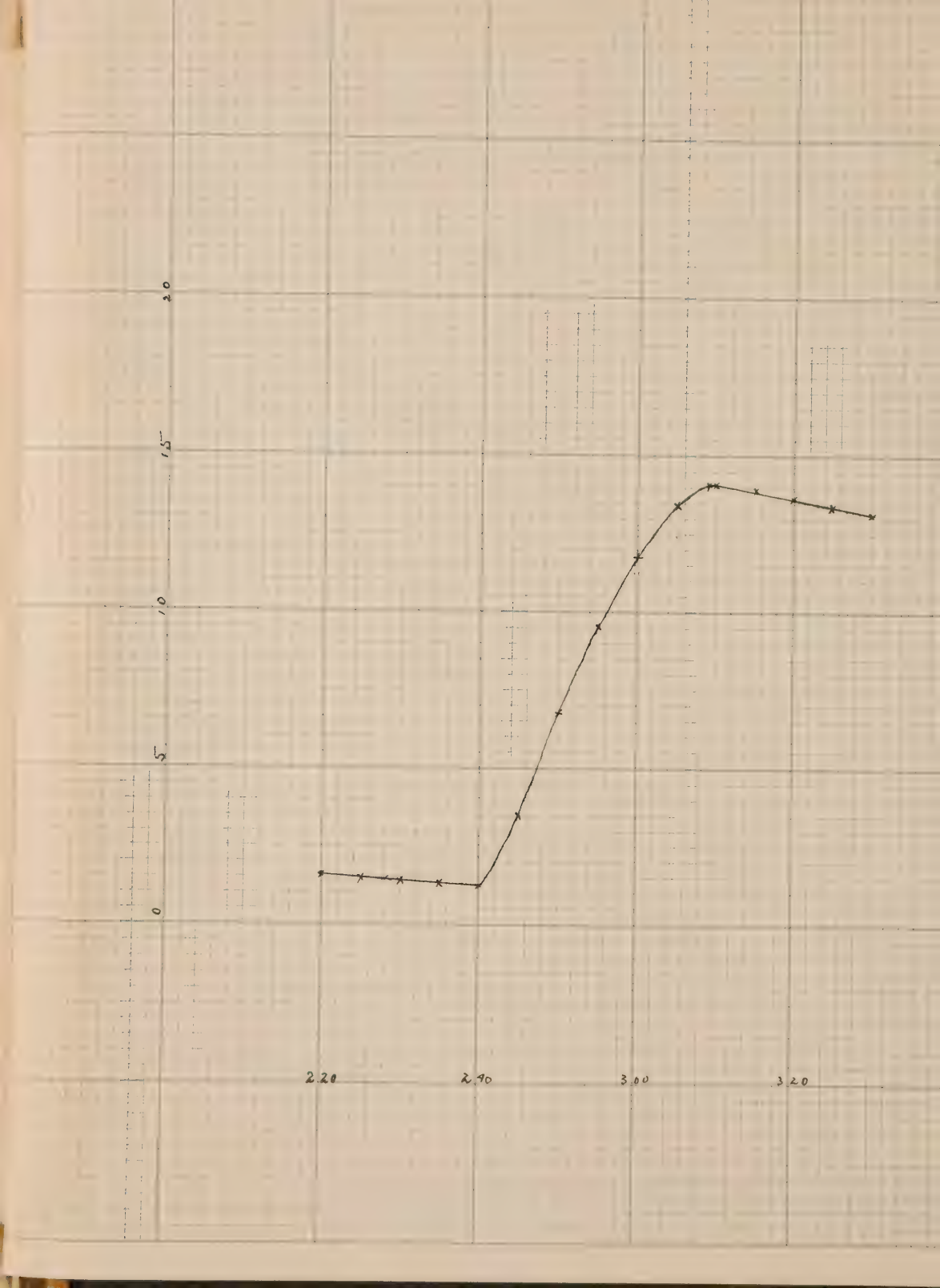
radiation curves

Coal ignited at 12.22 o'clock

Coal consumed at 12.48 o'clock

Table #13

TIME	SCALE	TEMP	OXY. PRESS
2.20	1.56	75.5	8.8
2.25	1.47	75.5	8.6
2.30	1.38	77.5	9.4
2.35	1.30	77.5	9.2
2.40	1.21	77.5	
2.45	3.18	77.5	8.8
2.50	6.75	77.5	9.0
2.55	9.53	77.5	9.2
3.00	11.74	78.0	9.2
3.05	13.42	78.5	9.2
3.09	14.07		
3.10	14.07	78.5	9.2
3.15	13.91	78.5	9.2
3.20	13.66	78.5	9.2
3.25	13.42	78.5	9.2
3.30	13.15	78.5	9.2


2.0
1.5
1.0
.5
0
2.20
2.40
3.00
3.20

Curve #13

Heat added by burning coal in body of calorimeter

Curve between 2.20 & 2.40, & between 3.09 & 3.30,

radiation curves

Coal ignited at 2.40 o'clock

Coal consumed at 3.09 o'clock

Table #14

TIME	SCALE	TEMP	OXY. PRESS
4.00	8.93	78.5°	9.0
4.05	8.77	78.5°	9.2
4.10	8.55	78.5°	9.4
4.15	8.34	78.5°	9.2
4.20	10.70	79.0	9.2
4.25	12.50	79.0	9.2
4.29	13.08		
4.30	13.08	79.5°	9.4
4.35	12.92	79.5°	9.4
4.40	12.68	79.5°	9.2
4.45	12.40	79.5°	9.2

Test # 14

Coal dried for 45 min between 212° & 230° F

Wt. crucible = 1.435

Wt. cruc + coal = 1.950

Wt. cruc + ash = 1.470

Wt coal = .515 grams Wt combustable = 4.80 gms.

Wt ash = .035 " % ash = 6.79 %

Rise in column before burning (15 min) = -.59 sc. div

" per hour " " = -2.36

" in column after " (15 min) = -.68 sc div.

" per hour " " = -2.72

Correction for radiation = $\frac{-2.36 - 2.72}{2}$ = -2.54 sc. div. per hr.

Rise of column due to burning (14 min) = 4.74 sc. div

correction for radiation (14 min) = -.593 sc. div

Corrected rise due to burning = 5.33 sc. div

Rise of column per gram combustable =

$\frac{5.33}{4.80}$ = 11.1 sc. div

Rise of column per gram coal =

$\frac{5.33}{.515}$ = 10.35 sc. div

20
15
10
5
0
4.00
4.20
4.40
5.00

Curve #14

Heat added by burning coal in body of calorimeter

Curve between 4.00 & 4.15, & between 4.30 & 4.45,

radiation curves.

Coal ignited at 4.15 o'clock

Coal consumed at 4.29 o'clock

Averages of results obtained.

By method of passage of current:

First method, as given by printed instructions

TEST #1 { 2.99, 3.97, 3.67 }
TEST #2 { 2.69, 2.80 }
TEST #3 { 3.11, 3.16 } B.T.U. per sc. div. rise of colum.

7) 22.39

Mean = 3.199 B.T.U. per scale division rise

Second method, see text.

TEST #4 — 3.37 B.T.U. per sc. div. rise
TEST #5 — 3.20 " " " "

2) 6.57

Mean = 3.285 B.T.U. per scale div.

By method of burning coal in calorimeter.

TEST #6	9.38		8.89
#7	10.90		10.20
8	11.5		10.8
9	8.70		8.13
10	10.0		9.36
11	9.17		8.56
12	9.38		8.72
13	10.3		9.65
14	11.1		10.35
	9) 90.43		9) 84.66
	Mean = 10.048		Mean = 9.407

Rise of colum in scale divisions per gram combustable

Rise of colum in scale divisions per gram combustable.

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